

## Revision Notes for Class 11 Biology

### Chapter 14 – Breathing And Exchange Of Gases

All biological activities require energy to take place and this energy is released by the decomposition of food. So all living things consume food to get high-energy organic molecules that release energy after their decomposition.

The decomposition of food in the presence of oxygen is called oxidation. Cells use oxygen to break down complex molecules and produce energy together with oxygen.

Breathing is the process of exchanging atmospheric oxygen with carbon dioxide which is produced by the cells.

The process of oxidation of complex food molecules into simpler molecules within the living cells of an organism is called respiration. The term 'Respiration' was coined by Dutrochet. During the oxidation process, the chemical energy stored in the food as complex molecules is released and is temporarily stored in the form of ATP. Breathing is the first step of the respiration process. The molecules of food substances that are decomposed during the respiration process are called respiratory substrates. For example glucose, amino acids, fatty acids, etc.

#### 14.1 Respiratory Organs:

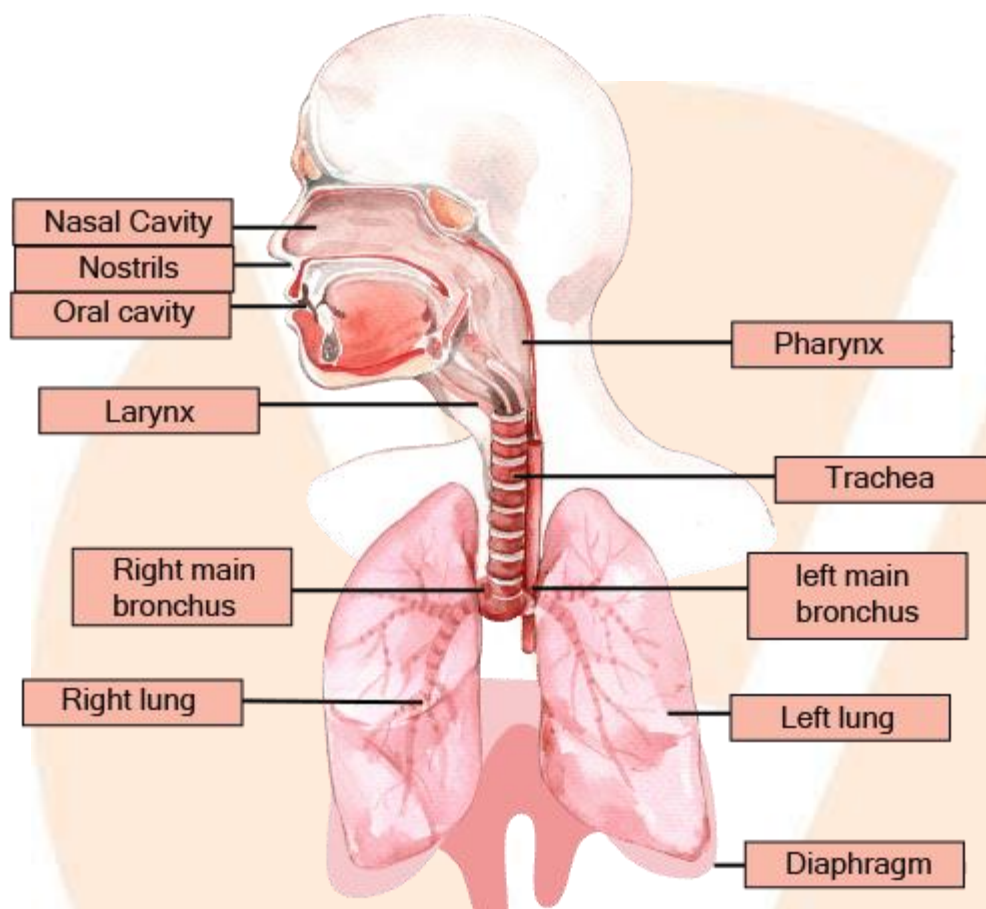
Depending on the body structure and habitat of organisms, the respiratory mechanism is different in different types of organisms and so are the respiratory organs present in them. A table is given below in which organisms and their respiratory organs are given:

Organisms		Respiratory Organs
1.	Mammals	Lungs
2.	Fishes, Molluscs, and aquatic Arthropods	Gills
3.	Amphibians	Moist skin and Lungs
4.	Insects	Tracheal system
5.	Earthworm	Moist skin
6.	Sponges, Coelenterates, and Flatworms	Body surface

#### 14.1.1 Human Respiratory System:

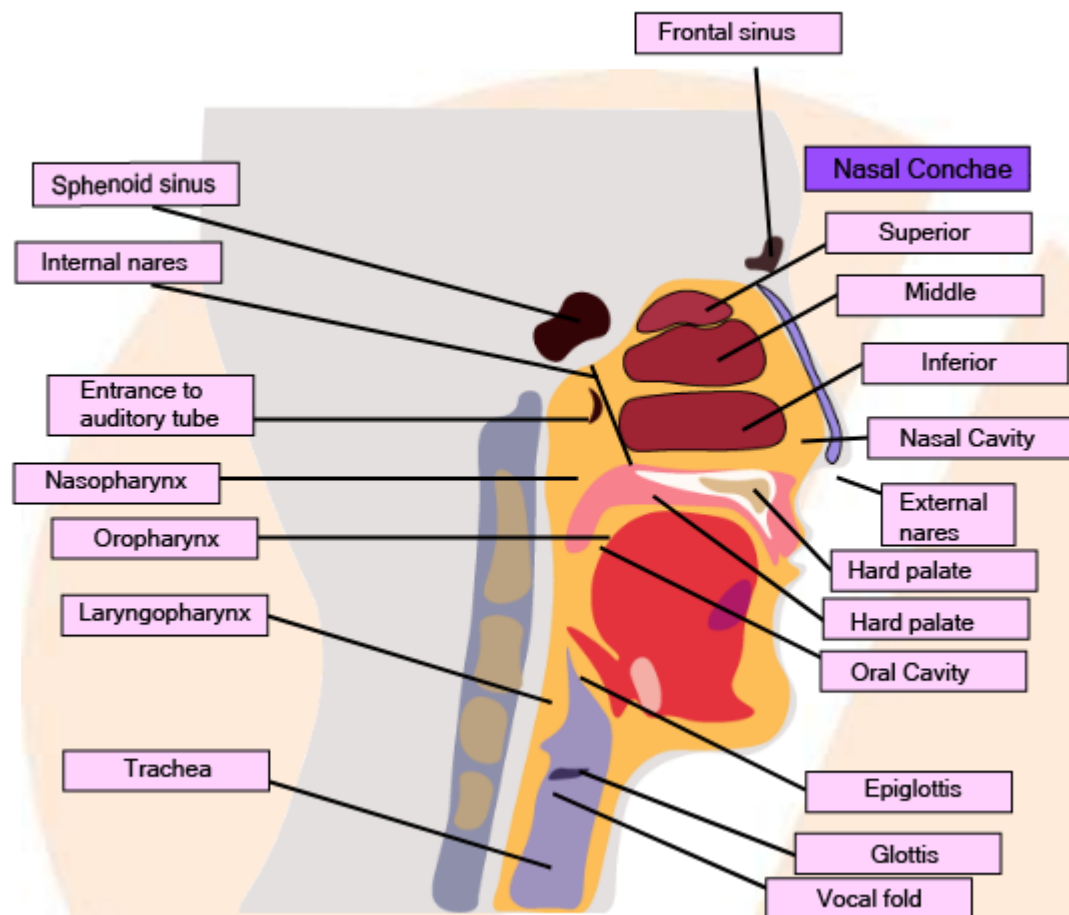
The human respiratory system begins with external nostrils which open into the nasal cavity. The nasal cavity extends into the nasal passage that consists of the larynx, trachea, bronchi, and bronchioles.

The nasal cavity is lined with mucous-secreting cells which secrete a slimy fluid called mucous. It can capture dust and other foreign objects in the inhaled air by keeping the nasal cavity moist. The dust particles present in the air are filtered by the hair present in the nasal cavity. The nasal cavity ends in the beginning part of the pharynx.



## Human Respiratory System

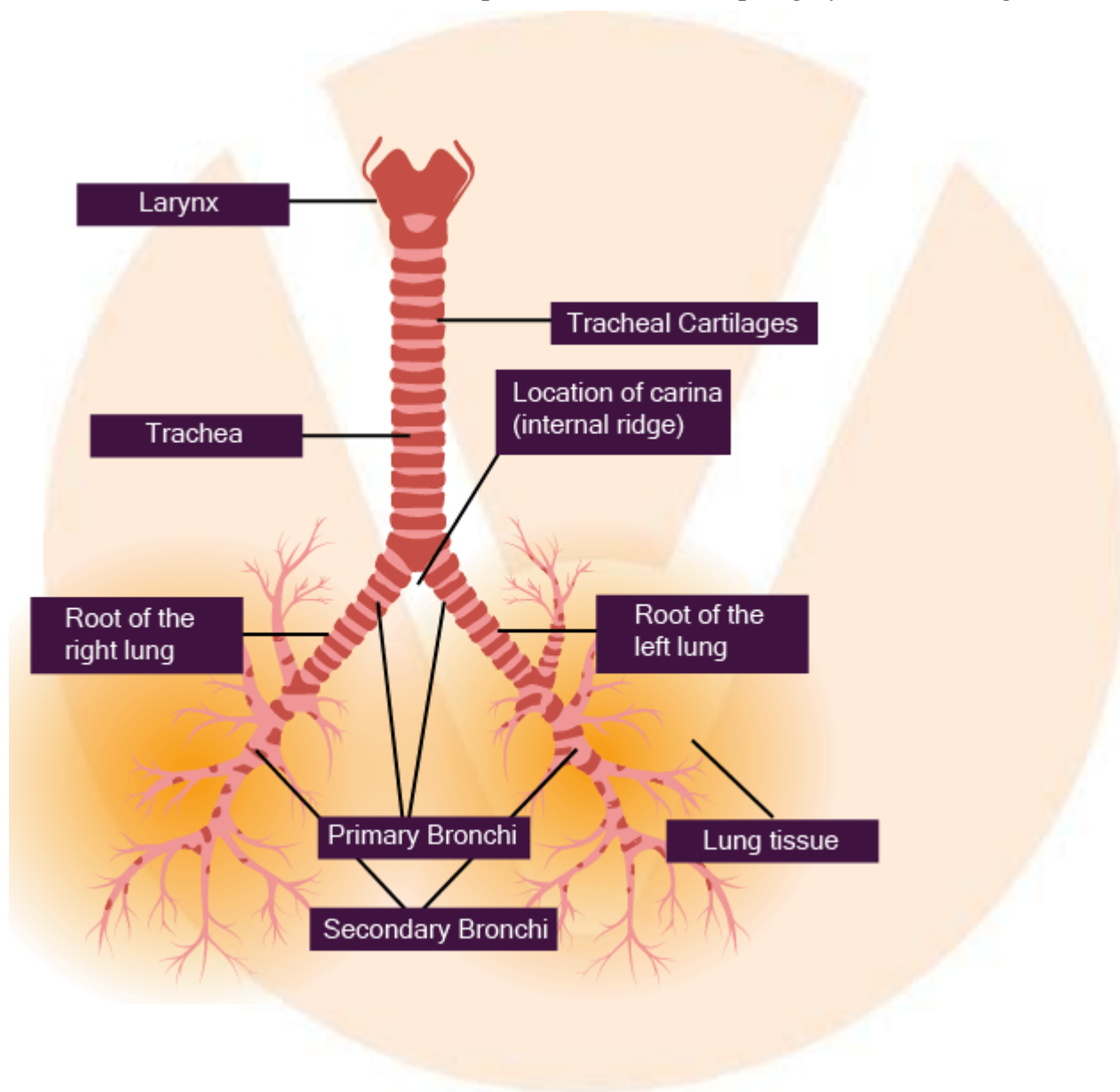
The pharynx is the junction between the respiratory and digestive systems. The oropharynx, Nasopharynx, and Laryngopharynx are the three sections of the pharynx. The oropharynx is the section of the pharynx behind the oral cavity that allows food to pass through, while the nasopharynx is the part that allows air to flow through. The region of the pharynx behind the larynx is known as the laryngopharynx. The glottis, a slit-shaped aperture at the bottom of the nasopharynx, is protected by the epiglottis, a cartilaginous flap. The main purpose of the epiglottis is to keep food from entering the trachea while swallowing. The glottis opens into the windpipe or trachea, a thin-walled tube that lies in front of the oesophagus and travels through the neck.



### Labelled Diagram of Nasal and Throat Cavity

The larynx is the enlarged, upper part of the trachea, meant to produce sound. Cartilage rings like thyroid cartilage and cricoid cartilage support the walls of the larynx. In the case of men, the thyroid cartilage is large in size protrudes from the neck, and is called Adam's apple. There are two mucous membranes present in the throat cavity and these membranes are called vocal cords. The vocal cords vibrate which in turn produce sounds.

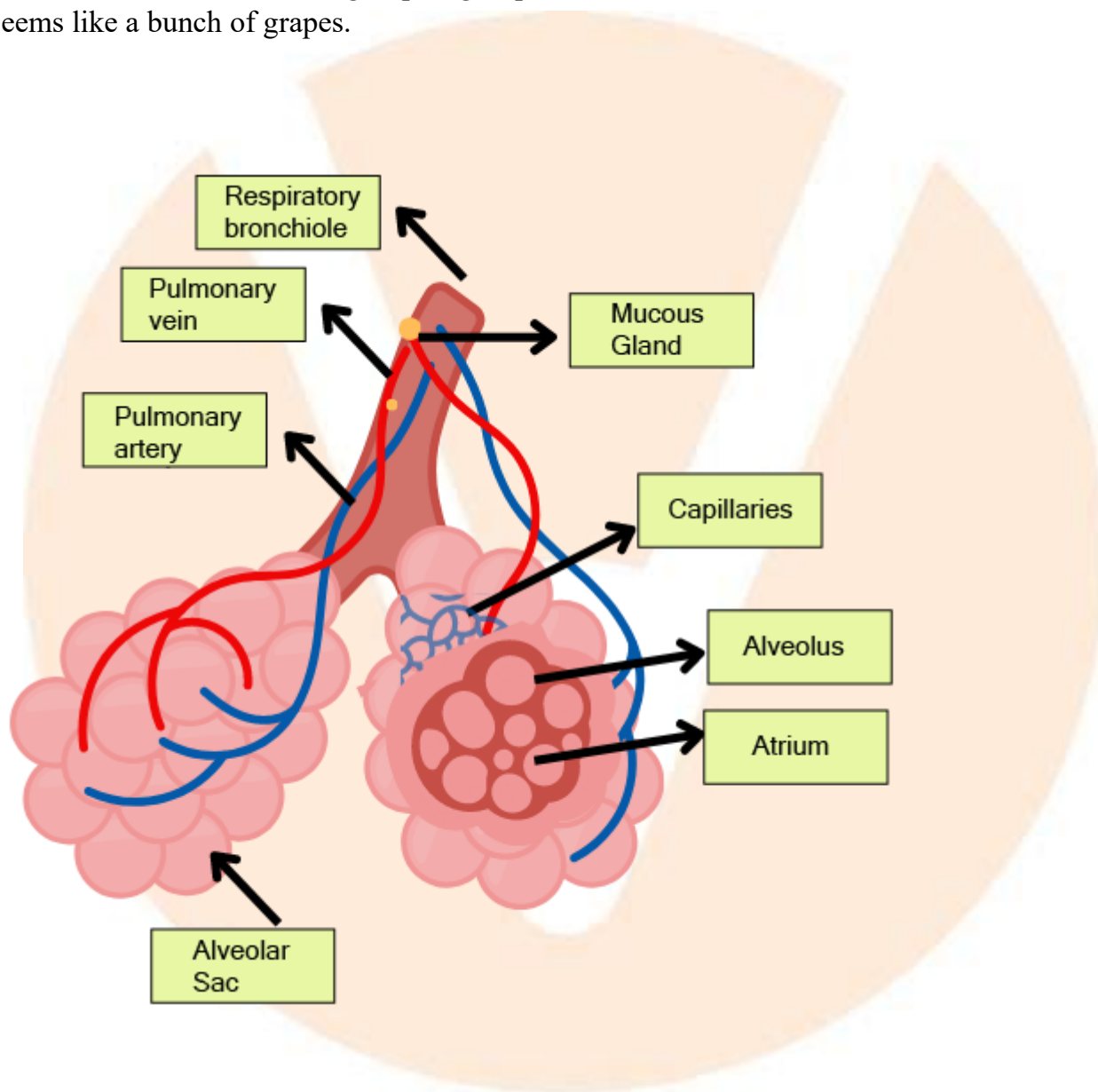
The trachea is protected by C-shaped rings made up of cartilage. When there is less air in the trachea, the wall of the trachea can be prevented from collapsing by these cartilaginous rings.



### Labeled Diagram of Trachea

The trachea is further divided into two bronchi which then enter into the lungs. Each lung has one of these two bronchi. Both of the bronchi divides again to form bronchioles, which spread in the entire lungs. Each of the bronchioles is divided into several tiny ducts named

alveolar ducts. Each alveolar duct is inflated into thin-walled air sacs called alveoli. Infundibulum is the alveolar group or group of alveoli. Therefore, each of the infundibula seems like a bunch of grapes.



### Labeled Diagram of Alveoli

The bronchi, bronchioles, and alveoli are the major components of the lungs. Both of the lungs are protected by a double-layered membrane called the pleura. The pleura is filled with



pleural fluid, which reduces friction on the surface of the lungs. The external pleural layer is in contact with the thoracic lining and the internal pleural layer is in contact with the surface of the lung.

### **The Respiratory System is Divided Into Two Parts:**

- 1. The Conduction Part:** The conduction part comprises all the respiratory components from the nostrils to the alveoli of the lungs. The function of this part is to conduct atmospheric air from external nostrils to the alveoli of the lungs. This part also prevents foreign objects from entering the respiratory passage, it moisturises the transporting air and brings its temperature close to the body temperature.
- 2. The Exchange Part:** The exchange part consists of the site where Oxygen diffuses between the blood and the atmospheric air present in the lungs.

The lungs are present in the chest cavity. Their dorsal side is bounded by the spine, the ventral side is bounded by the sternum, both of the lateral sides are bounded with ribs, and the bottom with a dome-shaped muscular sheet called the diaphragm.

Any changes in the chest cavity volume are expressed in the lung cavity and this change is necessary for breathing.

### **The Steps Involved in Breathing and Respiration Processes Are Given Below:**

- The first step is breathing or lung ventilation (inhalation of atmospheric air and exhalation of alveolar air rich in carbon dioxide).
- In the second step, gases(oxygen and carbon dioxide) diffuse through the alveolar membrane
- In the next step, diffused gases are transported through the blood to their target organs.

- Then diffusion of oxygen and carbon dioxide gases occurs between blood and body tissues.
- The body cells use oxygen for catabolic reactions and the resulting release of carbon dioxide gas. This process is also known as cellular respiration.

### 14.2 Mechanism of Respiration:

The influx and efflux of atmospheric air in the lungs, between the atmosphere and alveoli, is called breathing. It is a consequence of the expansion and contraction of the lungs.

The lungs contract in two processes:

- Inspiration or Inhalation
- Expiration or Exhalation.

A pressure gradient is created between the lungs and the atmosphere, to accomplish both of the above processes.

**Inspiration or Inhalation:** It is an active process that means it uses energy to take place and mainly includes muscle contraction. It occurs when the pressure inside the lungs is less than atmospheric pressure. The lungs are located in the chest or thorax. Contraction of the diaphragm (the muscular sheet that divides the chest and abdomen) and some intercostal muscles (muscles present between the ribs) occur during inhalation, as a result, the ribs are pulled up and in the outward direction. This process results in increasing the volume of the chest cavity because the sternum increases the volume of the thoracic cavity in the dorsal-ventral axis. An overall increase in the volume of the thoracic cavity also increases the volume of the lungs. Increased lung or pulmonary volume reduces the pressure inside the lungs. As a result, fresh air enters the lungs through the nose.

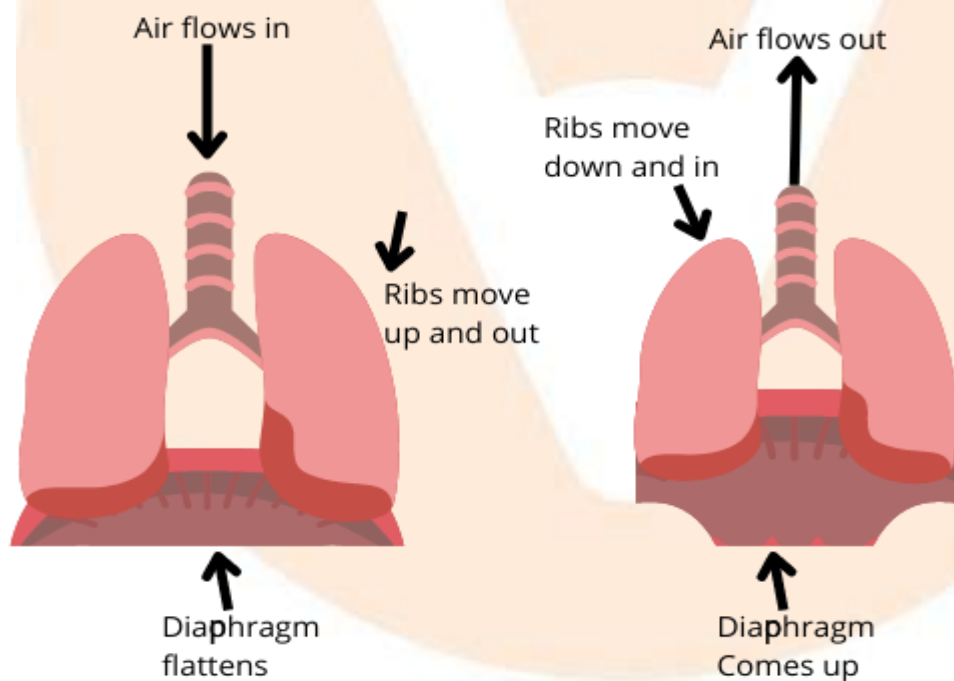


**Expiration or Exhalation:** Relaxation of the diaphragm and intercostal muscles causes the diaphragm and sternum to return back to their normal positions. This results in a reduction of the thoracic volume (volume of the chest cavity) and pulmonary volume (volume of lungs) but increases the intrapulmonary pressure (pressure inside lungs). This pressure is slightly higher than the atmospheric pressure, which causes the air to be expelled from the lungs.

The strength of inhalation and exhalation can be increased with the help of extra-abdominal muscles.

A healthy person normally breathes 12-16 times per minute, which is about 10 litres of air per minute.

The device used to measure respiratory rate is known as a spirometer or respirometer.



**Diagram Showing Mechanism of Respiration**

### 14.2.1 Respiratory Volumes and Capacities:

The air that enters and exits the lungs with each respiration is known as tidal air.

**1. Tidal volume (TV):** The volume of air inhaled or exhaled during normal breathing is known as the tidal volume. The tidal volume of an adult male is approximately 500 ml. A healthy person can inhale or exhale about 6000-8000 ml of air per minute.

**2. Inspiratory reserve volume (IRV):** This is the amount of additional air that can be inhaled beyond the normal tidal volume during a forced inhalation. The IRV of a normal person is approximately 2000-3000 ml.

**3. Expiratory reserve volume (ERV):** This is the additional volume of air that can be exhaled beyond the normal tidal volume during a forced exhalation. The ERV of a normal person is approximately 1100 ml.

**4. Residual volume (RV):** The residual air volume is the volume of air left in the lungs after forced exhalation. The RV of a normal person is approximately 1100 to 1200 ml. There is always a residual air volume left in the lungs so that even after forced exhalation, gas exchange will continue in the lungs.

**5. Pulmonary capacity (PC):** The pulmonary capacity is the capacity when two or more lung capacities are considered together.

The important pulmonary capacities of the lungs are given below:

**Inspiratory capacity:** The total amount of air that a person can inhale after a normal exhalation, is called inspiratory volume. It includes inspiratory reserve and tidal volume.

$$IC = TV + IRV$$

$$3500 \text{ mL} + 500 \text{ mL} = 3500 \text{ mL}$$

**Expiratory Capacity:** The amount of air that a person can exhale after a normal inhalation.

$$EC = TV + ERV$$

**Functional Residual Volume:** The amount of air left in the lungs after a normal exhalation. It is the sum total of the expiratory reserve volume and residual volume.

$$FRC = ERV + RV$$

$$2500 \text{ ml} = 1000 \text{ ml} + 1500 \text{ ml}$$

**Vital Capacity:** This is the amount of air that is expelled forcefully, after the deepest inhalation. It can be calculated by sum total of inspiratory reserve volume, expiratory reserve volume, and tidal volume.

$$CV = IRV + ERV + TV$$

$$4500 \text{ ml} = 3000 \text{ ml} + 500 \text{ ml} + 1000 \text{ ml}$$

**Total Lung Volume:** The maximum amount of air that the lung can hold is the total lung volume. It is the sum total of inspiratory reserve volume, expiratory reserve volume, tidal volume, and residual volume.

$$TLC = IRV + ERV + TV + RV \text{ or}$$

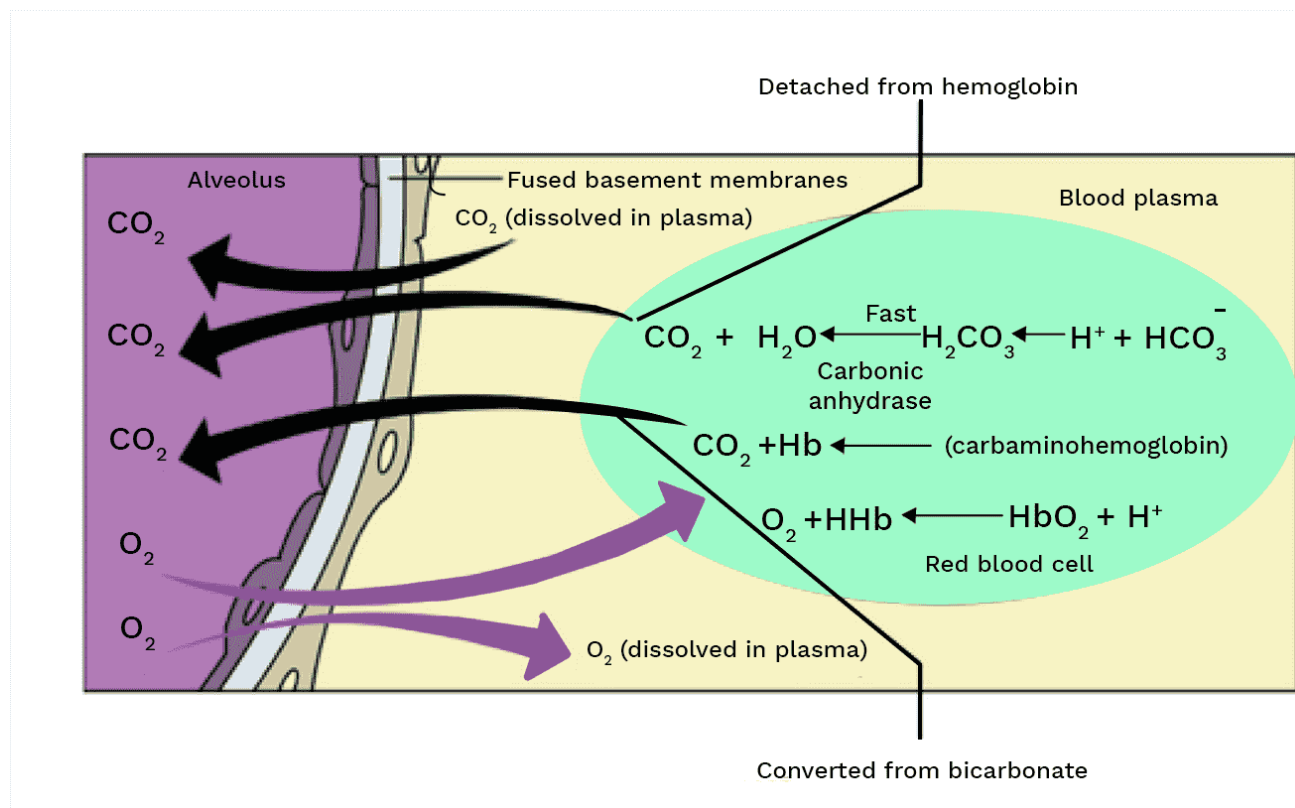
$$TLC = VC + RV$$

### 14.3 Gas Exchange:

The main part of gas exchange occurs in the alveoli. The exchange of gases takes place between blood and tissues. Gas exchange occurs by simple diffusion based on a pressure gradient or a concentration gradient. The solubility of the gas and the thickness of the film are the important factors affecting diffusion. The partial pressure is the pressure of a single gas in a gas mixture. The partial pressure of oxygen is represented by  $pO_2$ , and the  $m$ =partial pressure of carbon dioxide is represented by  $pCO_2$ .

Respiratory Gases	Partial Pressure mm Hg				
	Atmospheric air	Alveoli	Deoxygenated Blood	Oxygenated Blood	Tissues
$O_2$	159	104	40	95	40
$CO_2$	0.3	40	45	40	45

Partial pressures of oxygen and carbon dioxide (in mm Hg) at different parts as compared to the other gases present in the atmosphere



### Diagrammatic Representation of Gas Exchange Between Alveoli and Other Body Parts

The amount of  $\text{CO}_2$  that can diffuse through the diffusion membrane is greater than the  $\text{O}_2$  partial pressure. The diffusion membrane is formed by the layer of the squamous epithelium of the alveoli, the endothelium of the capillaries of the alveoli and the basement material between the two layers. The total thickness of the diffusion membrane is less than one millimetre. The diffusion of  $\text{O}_2$  from the alveoli to the tissues and the diffusion of  $\text{CO}_2$  from the tissues to the alveoli are aided by all variables in our bodies.

#### 14.4 Gas Transportation:

Both  $\text{O}_2$  and  $\text{CO}_2$  gases are transported through the blood. It is reported that 97% of  $\text{O}_2$  is transported by red blood cells and the remaining 3% is transported through plasma.

However, 20-25% of  $\text{CO}_2$  is transported through RBC, 70% is transported as bicarbonate ions, and the remaining 5-7% of  $\text{CO}_2$  dissolves in plasma.

#### 14.4.1 Oxygen Transportation:

The red blood cells contain a red-coloured iron-containing pigment that is known as haemoglobin. The iron part of haemoglobin binds with oxygen to form oxyhemoglobin, a combination that is related to the partial pressure of oxygen. One haemoglobin can carry four molecules of oxygen because one molecule of haemoglobin contains four iron-containing parts to which oxygen binds. The binding of oxygen with haemoglobin is affected by  $\text{CO}_2$  partial pressure, hydrogen ion concentration (pH), and temperature.

The relationship between haemoglobin and oxygen is expressed by plotting per cent saturation of haemoglobin with oxygen against partial pressure of oxygen. This curve is called the oxygen-dissociation curve or oxygen haemoglobin dissociation curve and it is a sigmoid or S-shaped curve.

Oxyhaemoglobin is formed in the alveoli when the  $\text{pO}_2$  is high, the  $\text{pCO}_2$  is low, the  $\text{H}^+$  concentration is low, and the temperature is low. Low  $\text{pO}_2$ , high  $\text{pCO}_2$ , high  $\text{H}^+$  concentration, and higher temperature occur in the tissues, resulting in oxygen dissociation from oxyhaemoglobin. Hence, oxygen binds to the haemoglobin on the lung surface and is dissociated from the haemoglobin in the tissues. Under normal physiological conditions, 100 mL of oxygenated blood provides about 5mL of oxygen.

#### 14.4.2 Carbon Dioxide Transportation:

$\text{CO}_2$  combines with haemoglobin to form carbamino-haemoglobin, which is proportional to  $\text{CO}_2$  partial pressure. The binding of carbon dioxide with haemoglobin is affected by the partial pressure of  $\text{O}_2$ . More binding occurs when the partial pressure of  $\text{CO}_2$  is high and the partial pressure of  $\text{O}_2$  is low, as more carbon dioxide binding occurs in tissues. When the  $\text{pCO}_2$  is low and the  $\text{pO}_2$  is high, as in the alveoli,  $\text{CO}_2$  dissociates from carbamino-haemoglobin.



The carbonic anhydrase enzyme is abundant in RBCs and is responsible for converting carbon dioxide into bicarbonate ions. This enzyme is only found in trace amounts in plasma.

Because of catabolism, the partial pressure of  $\text{CO}_2$  in the tissue is high, and it diffuses into the blood to form  $\text{HCO}_3^-$  and  $\text{H}^+$  ions.

$\text{CO}_2$  and  $\text{H}_2$  are formed when the partial pressure of  $\text{CO}_2$  in the alveolus is low. Bicarbonate ions are formed as a result of carbon dioxide trapping. It moves from the tissue to the alveoli, where carbon dioxide is expelled. 4 mL of carbon dioxide is delivered for every 100 mL of deoxygenated blood.

### **14.5 Regulation of Respiration Process:**

The nervous system regulates the process of respiration or respiratory rhythm. The rate of respiration changes in response to the body's oxygen demand. The respiratory centre is the regulatory centre for respiration. It is made up of a number of neurons located bilaterally in the brain's medulla oblongata. There are three types of respiratory centres: respiratory rhythm centre, pneumatic centre, and chemosensitive area.

#### **14.5.1 Respiratory Rhythm Center:**

It is a group of neurons in the medulla oblongata's dorsal region. It is a specialised centre that is in charge of respiration regulation. The basic respiratory rhythm is produced by this group of neurons. Neurons of the respiratory rhythm centre release nervous signals which are transmitted to the diaphragm, the primary inspiratory muscle. These signals cause the inspiratory muscle (diaphragm) to contract, resulting in inspiration.

#### **14.5.2 Pneumotaxic Centre:**

It is a group of neurons located dorsally in the brain's upper pons. It has the ability to modulate the functions of the respiratory rhythm centre.

The number and depth of breaths are determined by the signal from the neurons of the pneumatic centre. When the pneumatic centre sends a strong signal, the rate of breathing increases due to the shortening of both inspiration and expiration. The neural signals from the pneumatic centre can also shorten the duration of inspiration and thus change the rate of respiration.

### 14.5.3 Chemo Sensitive Centre:

This is a region near the respiratory rhythm centre that is extremely sensitive to CO<sub>2</sub> and hydrogen ions. The concentration of hydrogen ions and CO<sub>2</sub> raises the inspiratory and expiratory signals. There is no direct effect of oxygen on respiratory signals. The chemosensitive centre is activated by the increased concentration of CO<sub>2</sub> and Hydrogen ions in the chemosensitive area. Then the signals are transmitted to the respiratory rhythm centre, which adjusts the respiratory process to eliminate these substances.

Changes in the concentration of CO<sub>2</sub> and hydrogen ions are recognised by aortic arch and carotid artery receptors. They send the necessary signals to the respiratory rhythm centre in order for immediate control actions to be taken.

### 14.7.6 Disorders of the Respiratory System:

Many respiratory diseases and respiratory disorders affect the human respiratory system. Asthma, emphysema, and occupational respiratory disorders are all common.

**Asthma:** Asthma is characterised by difficulty breathing and wheezing caused by inflammation of the bronchi and bronchioles.

**Emphysema:** Emphysema is a chronic obstructive lung disease. It is characterised by abnormal distension or inflation of the alveolar wall, resulting in a loss of elasticity of their walls. Alveolar walls degenerate, and alveoli join together to form large alveoli. Even during expiration, the alveoli remain completely filled with air. This causes an increase in lung size, and cigarette smoking is the leading cause of emphysema.

**Occupational Respiratory Disorders:** Occupational respiratory disorders are pulmonary diseases caused by exposure to potentially harmful substances such as gas, fumes, or dust in a person's working environment. Silicosis (caused in workers employed in the mining industry, quarry, etc. due to chronic exposure to silica dust from rocks or stones) and asbestosis (caused in workers employed in asbestos factories due to chronic exposure to asbestos dust) are two common examples.